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The ancillary services in China: An overview and key issues

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ABSTRACT

Under a market environment framework, ancillary services are an important guarantee of a power system's smooth operation. This paper presents a comprehensive discussion of the issues related to China's ancillary services in the electric power market. First, the status of ancillary service development in China is introduced, and then specific issues are analysed in depth. Finally, feasible policy recommendations for the issues are proposed. This study has important and practical implications for the development of ancillary services in China.

Contents

1. Introduction

Both electricity production and consumption are in a real-time balanced system. Any load fluctuation, power grid accident, change in electrical equipment or problem in a generating unit could affect the system's balance. As a result of the constantly expanding capacity of China's power system, issues that concern power supply and demand, such as electricity shortages during peak period, widening peak-valley differences, and the growing impact of the climate and environment on the system's load, are becoming more prevalent [1]. Meanwhile, China has an abundance of hydropower and wind power resources and is accelerating the development of a smart grid. A large amount of the electricity generated from clean energy needs to be connected to the grid. Hydropower ranks second only to coal as the largest conventional energy in China. Its installed capacity in 2010 was approximately 210 GW, and the annual generating capacity was approximately 610×10^3 GWh. At the end of year 2011, the total installed capacity of hydropower in China reached 220 GW. In the case of wind power, China (excluding Taiwan) had 11,409 new wind turbines

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installed in 2011, and their installed capacity was 17,630.9 MW. At that time, the total number of installed wind turbines reached 45,894 providing a capacity of 62,364.2 MW at an annual growth rate of 39.4% [2]. Clean energy connected to the grid has alleviated the disparity between China's power supply and demand, but its output has intermittency and fluctuation. For example, China's frequent extreme weather weakens the peak capacity of hydropower. Moreover, the randomness, intermittency and instability of wind power hamper both power quality and safe, stable operation of the power grid. Between January and August 2011 alone, 193 off-grid wind turbine accidents occurred. In addition, transmission contact lines will gradually increase with the development of China's ultra-high voltage (UHV) infrastructure [3]. When the UHV grid that will cover the whole country is built, it will pose greater challenges to the stability of the power system and power quality, which requires electricity enterprises not only to provide supply and transmission services for their users but also to provide ancillary services to maintain the balance and stability of the power system [4]. Power grid operation and control has become increasingly complex because of the need for more ancillary services to solve the problems in China's power system, which result from renewable energy, such as grid connection and peak shaving.

Therefore, this paper has thoroughly analysed the status quo of China's ancillary services with a focus on their implementation, their pricing mechanisms and the rights and responsibilities of various market players. The existing issues in China's ancillary services have also been explored. Finally, some ideas to improve ancillary services in China were proposed covering the construction, the pricing mechanism and the assessment compensation of the ancillary services market.

2. Status quo of the ancillary services in China

2.1. The ancillary services policies

China's electricity market has long been heavily regulated by administrative and planning institutions. After the separation of power generation and transmission, several prominent deficiencies in ancillary services emerged. Thus, addressing the issues related to ancillary services using market-based instruments gradually becomes a necessity. As an important part of the electricity market, ancillary services should be carried out in line with the established policies of the energy market. In keeping with this idea, the State Electricity Regulatory Commission (SERC) issued the "Interim Measures of Ancillary Services Management for Grid-connected Power Plants" (electricity regulatory market [2006] No.43) in 2006, which designates ancillary services as one of the priorities of electricity market reforms in the future and defines the concept of ancillary services. Ancillary services are the services provided by power generation companies, grid enterprises and consumers that, in addition to the normal electricity production, transmission and consumption, ensure quality power and the power system's safe and stable operation [5]. Meanwhile, "The Interim Measures" makes it clear that the entire group of generation units offering ancillary services is comprised of provincial and above-power dispatch and transaction institutions as well as the thermal and hydroelectric power plants directly scheduled by them. Further, ancillary services are divided into basic ancillary services and paid ancillary services. Basic ancillary services, including primary frequency, basic peaking and basic reactive power regulation, are mandatory services provided by grid-connected power plants to ensure the power system's safe and stable operation and quality. Paid ancillary services, including automatic generation control (AGC), reserve, paid peaking, paid reactive power regulation and black start, are services provided by grid-connected power plants in addition to the basic ancillary services [6]. It is necessary to compensate for paid ancillary services. When grid-connected power plants, for their own reasons, cause ancillary services to not be called or to not meet the requirements, they should receive an assessment. Compensation costs for ancillary services have an independent account in the grid enterprises of various provinces (municipalities) and are under special control. They are settled monthly as electricity charges. Furthermore, some paid ancillary services are extended to the regional power grids, and the regional electricity regulatory commissions are required to formulate detailed implementation rules according to the actual configurations of regional power systems [7], as shown in Fig. 1, Tables 1 and 2.

At the end of 2008, the State Electricity Regulatory Commission formally agreed with the six regions (South China, North China, East China, Central China, Northeast China and Northwest China) to put forth "The Detailed Implementation Rules of Power Plants for Ancillary Services Management and Grid-connected Operation" (hereinafter referred to as the "two rules"). The "two rules" were required to start a trial run in the first half of 2009 and then facilitated an official run in the second half of 2009 [8]. In addition, the implementation of Central China's "two rules" demonstrated that China's ancillary services management began to move toward standardized management. The ancillary services-related policies promulgated by China are shown in Table 3. The definition and classification, supply and invoking, measurement and assessment, methods of compensation and cost source, and supervision and management of ancillary services (referred to as details of ancillary services briefly in Table 3) in different regions are formulated in different policies accordingly.

In China's ancillary power services market's present state, the electricity regulatory agencies are primarily responsible for formulating standards; supervising and evaluating ancillary services; organising and entrusting qualified firms to assess the capability of grid-connected generation units offering ancillary services; coordinating controversies related to the invoking, appraisal and compensation of ancillary services between grid-connected power plants and power dispatch and trading institutions according to law; and disclosing the relevant information of the invoking, appraisal and compensation of ancillary services [9]. According to the conditions of generation units and the power grid, power dispatch and trading institutions invoke ancillary services by following the principle of "on-demand dispatching" and install the black-start power reasonably in accordance with the security requirements of the system [10]. To be concluded, the rights and responsibilities of transaction participants in ancillary services are listed as follows:

(1) Power generation enterprise

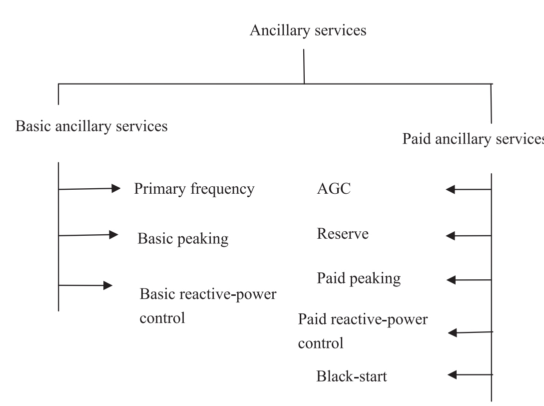


Fig. 1. A generic classification of ancillary services in China.

Table 1
Description of basic ancillary services.

Basic ancillary services	Description
Primary frequency	When the power system's frequency deviates from the target frequency, generation units will adjust the active power output through the automatic response of the speed control system.
Basic peaking	Within the regulated output adjustment range, generation units carry out planned output adjustments to track load changes.
Basic reactive power regulation	Generation units provide injecting or absorbing reactive power in the power system within the regulated power factor range.

Table 2
Contents of paid ancillary services.

Paid ancillary services	Contents
AGC	Generation units track the directions issued by the dispatch agencies and adjust the real-time power output within the regulated range in order to meet the requirements of power system frequency and contact lines frequency control.
Reserve	In order to ensure reliable power supply, the generation units assigned by the power dispatching and trading centres spare generating capacity. It includes spinning reserve and non-spinning reserve. Initially, only spinning reserve can be compensated.
Paid peaking	Generation units carry out peaking beyond the regulated peaking depth, and thermal power generating units start or stop service within the regulated time according to the requirements of the power dispatching and trading centres.
Paid reactive power regulation	Power dispatching and trading institutions require the generation units to inject or absorb reactive power beyond the specified power factor range.
Black-start	When the massive blackout occurs, generation units which have self-starting capability provide restoring the system power supply with no external power supply support.

Table 3
Policies of ancillary services.

Name of policy	Description	Effective date	Responsible agency
"Grid-connected plants' ancillary services compensation implementation details in North China "	Based on the actual situation in North China, formulates interim measures for the details of ancillary services in North China.	2004	National Development and Reform Commission; State Electricity Regulatory Commission
"Grid-connected plants' operation management implementation details"	Formulates the details of ancillary services in China.	2006	State Electricity Regulatory Commission
"Ancillary services management implementation details in the Southern Region" & "Grid-connected plants' operation management implementation details in the Southern Region"	Formulates the details of ancillary services in the Southern Region.	2009	Southern Region Authority of the State Electricity Regulatory Commission
"Ancillary services management implementation details in North China" & "Grid-connected plants' operation management implementation details in North China"	Formulates the details of ancillary services in North China.	2009	North China Authority of the State Electricity Regulatory Commission
"Ancillary services management implementation details in East China" & "Grid-connected plants' operation management implementation details in East China"	Formulates the details of ancillary services in East China.	2009	East China Authority of the State Electricity Regulatory Commission
"Ancillary services management implementation details in Central China" & "Grid-connected plants' operation management implementation details in Central China"	Formulates the details of ancillary services in Central China.	2009	Central China Authority of the State Electricity Regulatory Commission
"Ancillary services management implementation details in the Northeastern Region" & "Grid-connected plants' operation management implementation details in the Northeastern Region"	Formulates the details of ancillary services in the Northeastern Region.	2009	Northeastern Region Authority of the State Electricity Regulatory Commission
"Ancillary services management implementation details in the Northwestern Region" & "Grid-connected plants' operation management implementation details in the Northwestern Region"	Formulates the details of ancillary services in the Northwestern Region.	2009	Northwestern Region Authority of the State Electricity Regulatory Commission

(1) The grid-connected power plants should provide basic ancillary services including primary control, basic peaking and basic reactive power regulation;
(2) Paid ancillary services are services provided by the grid-connected power plants in addition to the basic ancillary services, including automatic generation control (AGC), reserve, paid peaking, paid reactive power regulation and black start;
(3) Before the ancillary services transaction, provide the basic technical parameters to determine the ability of each type of ancillary service, and offer the ancillary service the ability to test reports issued by qualified firms; responsible for the operation and maintenance of the equipment to ensure the ability to provide ancillary services that meet the required standards; provide ancillary services in accordance with the requirements of contracts and the dispatch centre; cooperate with and fulfil the verification of parameters;
(4) In accordance with its own production arrangements and the actual conditions, determine the transaction details, trading volume and transaction price: sign a bilateral agreement of purchase and sale directly with the consumer, not through operating agencies; report the demand information to the trading centre for matching;

(5) Obey the dispatching arrangements of scheduling institutions and respond positively to the relevant decision-making.

(2) Power grid corporation

(1) Monitor the real-time status of transmission lines, report the current transmission capacity, maintain scheduling and other information for the dispatch centre. Then, the dispatch centre carries out coordinated planning referring to the information;

(2) Responsible for the routine maintenance of the relative equipment and facilities to provide strong support for the implementation of ancillary services;

(3) Provide services for the ancillary service market according to the united planning of the dispatch centre.

(3) Consumer

(1) In accordance with its own production arrangements and the actual conditions, determine the transaction details, trading volume and transaction price: sign a bilateral agreement of purchase and sale directly with the consumer, not through operating agencies; report the demand information to the trading centre for matching;

(2) Obey the dispatching arrangements of scheduling institutions, and respond positively to the relevant decision-making.

(4) Trading centre

(1) Monitor the trading information of ancillary services including trading subjects, the volume and the price and then put it on record;

(2) Receive the purchase and sale information of ancillary services, carry out the matching of indicators in the system and then report the result to the dispatch centre to receive an audit;

(3) When carrying out the transaction from grid to grid, responsible for the allocation of external network indicators and the timely publication of the relevant information.

(5) Dispatch centre

(1) Implement ancillary service calls, statistics, assessments and compensation under the authority of the electricity regulatory agencies;

(2) Arrange the ancillary services of grid-connected power plants according to the grid conditions, safety guide, dispatch procedure and organisation; record and measure the implementation status of ancillary services; regularly publish the conditions of ancillary service calls, statistics and assessments; respond quickly to inquiries from the power generation companies; carry out statistical analysis of ancillary services on a regular basis, and submit the analysis to the electricity regulatory agencies; according to the requirements of the electricity regulatory agencies, submit other relevant circumstances;

(3) Check the parameters of generation units and submit parameter verification reports to the electricity regulatory agencies and the corresponding power dispatching agencies;

(4) When vacancies happen in ancillary services, start the network – network interactions for mutual transactions through a coordinated distribution of the dispatch centre;

(5) Power dispatch agencies are responsible for the organisation of the power enterprises to build the appropriate technical support system;

(6) The main technical support system is installed in the dispatch centre in charge of the measurements, statistics and settlements. The power generation enterprises can apply for the establishment of a sub-station in charge of the information query and feedback;

(7) The network and provinces' (municipalities) dispatch centres publish the ancillary services calls, statistics, and compensation conditions of the generation units for the previous month in their jurisdictions on the "Three Disclosure" website;

(8) If grid-connected plants doubt the statistical results, they can apply for a review to the appropriate power dispatch agencies. Within three working days after receiving the inquiry, the dispatching agencies should verify the situation and answer the plants;

(9) The dispatching agencies report the details of the ancillary services statistics of the last trading session to the electricity regulatory agencies;

(10) The electricity regulatory agencies are in charge of the regulation of the dispatching agencies that call ancillary services.

(6) Regulator

(1) Responsible for the supervision of ancillary service calls, statistics, assessment transactions;

(2) If controversies exist between a power plant and the regulators due to the above work, the local regulators should coordinate and adjudicate them in accordance with the law.

2.2. Comparison of ancillary services in different regions

With the continuing expansion of power system reforms, ancillary service policies developed by the State Electricity Regulatory Commission contribute to the promotion of the market-oriented process of ancillary services in China [11]. However, as the actual configuration of different regional power systems varies, the "two rules" issued by different regional power grids differ greatly, which is mainly reflected in the relationship among the costs of assessment and compensation, the cost-sharing mechanisms, the definition of basic ancillary services, the items considered as paid ancillary services, the scope and methods of specific compensation, and the standards of compensation. The differences are listed below:

(1) The peaking range varies. In the East China Power Grid, the basic peaking ranges of generation units dispatched by Shanghai, Jiangsu, Zhejiang, Anhui and Fujian Province are 100–53%, 100–41%, 100–41%, 100–43%, 100–35%, of the rated capacity, respectively. In the Southern Power Grid, the basic peaking range is 100–50% of the generation units' rated output. In the North China Power Grid, for thermal power units, the peaking standard should reach 50% of the rated capacity. For hydropower units it should reach 100%, while wind power and other clean energy generators provide peaking according to their capability [12].

(2) The response range of reactive-power control services varies. In the East China Power Grid, the criteria of basic reactive-power control is a late-phase power factor greater than 0.80 and an into-phase power factor greater than 0.95; the criteria of paid reactive-power control is a late-phase power factor less than 0.80 and an into-phase power factor less than 0.95. In the Southern Grid, the criteria of basic reactive-power control is a late-phase power factor greater than 0.90 and an into-phase power factor greater than 0.97; the criteria of paid reactive-power control is a late-phase power factor less than 0.90 and an into-phase power factor less than 0.97 [13].

(3) In the rules promulgated by each regional power grid, the assessment indicators of paid peaking, AGC, reactive power regulation, reserve and black start are shown in Table 4.

Table 4
The Aassessment indices of the regional market ancillary services in China.

	East China	Central China	North China	Northwest	Northeast	South
Paid peaking	Unit capacity, peaking power, time interval of start/stop	The number of start/ stop peaking, peaking coefficient	The number of start/stop peaking, unit capacity, peaking power	The power less than basic peaking power, start/stop unit capacity	The power less than basic peaking power, start/stop unit capacity	The amount of start/ stop peaking, unit capacity, peaking power
AGC	The rate of putting into operation, regulation accuracy, adjustment rate and the adjustment capacity	Probability of investing and adjustment accuracy, adjustment range and the corresponding rate	Compensation calculating time, the available capacity to adjust and the adjustment performance	Steal time, adjustment speed, adjustment accuracy and the corresponding time	Availability, adjustment capacity, adjustment speed, adjustment accuracy and the corresponding time	The rate of putting into operation, adjustment rate and the adjustment power
Reactive power	Bus voltage pass rate, the rate of putting into operation of AVC, AVC adjustment pass rate	Power factor, the hours of paid reactive power regulation	Bus voltage pass rate, the rate of putting into operation of AVC, AVC adjustment pass rate	Power factor, voltage pass rate, reactive power	Power factor, voltage pass rate, reactive power	Power factor, reactive power
Reserve	Reserve capacity, supply time	Reserve capacity, supply time	Reserve capacity, supply time	Reserve capacity, supply time	Reserve capacity, supply time	Reserve capacity, supply time
Black-start	New transformation investment cost, maintenance cost of testing, staff training costs	New transformation investment cost, maintenance cost of testing, staff training costs	New transformation investment cost, maintenance cost of testing, staff training costs	New transformation investment cost, maintenance cost of testing, staff training costs	New transformation investment cost, maintenance cost of testing, staff training costs	New transformation investment cost, maintenance cost of testing, staff training costs

Table 5
Compensation standards of ancillary services in Southern Region.

Standard compensation types of ancillary services	Responding symbol in the rules	Unit	Guangdong	Guangxi	Yunnan	Guizhou	Hainan
Compensation standards of AGC capacity adjusting	R1	Yuan/MWh	1.78	1.28	0.31	1.00	1.41
Compensation standards of AGC power adjusting	R2	Yuan/MWh	14.6	10.49	7.66	8.20	11.58
Compensation standards of on/off peaking	R3	Million/Ten thousand KW	1.04	0.71	0.93	0.56	0.79
Compensation standards of spinning reserve	R4	Yuan/MWh	3.53	2.540	Thermal: 18.40 Hydro: 44.35	1.986	2.804
Compensation standards of in-depth peaking	3 × R4	Yuan/MWh	10.59	7.62	55.2	5.985	8.412
Compensation standards of late-phase reactive power regulation	R5	Yuan/MWh	0.481	0.344	17.08	0.269	0.380
Compensation standards of into-phase reactive power regulation	3 × R5	Yuan/MWh	1.44	1.032	51.23	0.807	1.139
Compensation standards of Black-start capability	R6	Million/month/set	0.411	0.30	1.07	0.23	0.33
Compensation standards of Black-start using	R7	Million/set	480	360	300	300	150

(4) For paid peaking, AGC, reactive power regulation, reserve and black start, the standards of cost compensation vary: similar ancillary services in different markets have different compensation costs per capacity; different units in the same market have different compensation costs per capacity. Details are available in the ancillary services compensation rules of different regional electricity markets. The compensation standards of the Southern region are shown in Table 5.

2.3. *International comparison of ancillary services markets and enlightenment*

In England and Wales, ancillary services are operated by the National Grid Company (NGC), which is also in charge of the transmission grid. The costs in relation to the provision of ancillary services are shifted to the terminal consumers through an increase in transmission payment. In California, USA, the energy market, the congestion management market and the ancillary services market became simultaneously optimized, along with the identification of the generators that would be in charge of the delivery of energy and the other services. In Australia, the National Electricity Market Management Company Limited (NEMMCO) is the system operator, as well as the ancillary services market administrator. Beginning from 2001, frequency control ancillary services are traded in competitive spot markets.

However, ancillary services markets in different countries have a lot in common. From the aspect of types of services, there are mainly frequency regulation, reserves, reactive power regulation and black start. From the aspect of trading modes, ancillary services are generally traded through compulsory mode, bilateral contracts, biddings and competitive spot markets. From the point of the relationship between ancillary services and electricity dispatching, the dispatching modes of ancillary services are mainly Merit Order-based Dispatch, Sequential Dispatch and Joint Dispatch. From the aspect of cost-sharing mechanism, there are mainly 3 ways to apportion the ancillary services costs: apportionment among initiators of reserves, apportionment among beneficiaries of reserves, apportionment among all the market players.

In all, the development of ancillary services depends upon the electrical power system being considered. Power grid operation and control has become increasingly complex because of the need for more ancillary services to solve the problems in China's power system, which result from renewable energy, such as grid connection and peak shaving. Meanwhile, China's electricity market has long been heavily regulated by administrative and planning

institutions. Therefore, during the early construction period of the ancillary services market, China should learn from developed countries and can adopt a transition mode in which the compensation and marketization mechanisms mix together until the completely commercialised operation mechanism is achieved.

3. Key issues and challenges of ancillary services in China

In the past, because of factors such as a weak grid structure, imperfect market management mechanisms, insufficient reserve capacity, and a limited level of automatic generation control, the grid had been implementing centralised power dispatching to ensure safe operation without considering transactions in the ancillary service market. Therefore, all the ancillary services were directly invoked by the dispatch centres causing most of ancillary services to be free of charge, which affected the willingness of power generation companies to provide ancillary services and, to some extent, grid-supporting facilities. With the expansion of China's market-oriented reforms in the electricity industry and the increasingly stricter requirements for the power system's safe and economic operation, the marketization of ancillary services will inevitably become one of the key objectives of the reforms in the electricity market in the near future [14].

3.1. The slow process of ancillary services marketization

Affected by the State Grid and China Southern Power Grid, UHV, which is developing vigorously in China, has frequent power fluctuations with large amplitudes. Increasing transmission contact lines in UHV make grid structures more complex; thus, there is an increase in demand for ancillary services. For example, take the 1000 kV "Changzhi–Nanyang–Jingmen" transmission line joining Central China with North China, etc. Power plants in the two districts must not only provide ancillary services needed by the regions but also provide services needed by UHV transmission lines [15]. Due to the special requirements of the UHV, regional ACE control and the requirements for ancillary services become more stringent. Thus, the power plants that provide services for UHV transmission lines have heavier tasks, requiring more reserve capacity. Meanwhile, the output of power plants needs to vary frequently and substantially in accordance with the transmission lines, causing a great impact on the units' lifespans. Under circumstances of high capacity, long distance transmission and the expansion of interconnected power networks, the grid structure is weak, and the existing ancillary services cannot meet the demand for the power system's safe and stable operation. The part of the power grid that lacks reserve capacity still runs, posing a tremendous security risk. With the development of China's UHV construction, transmission lines will gradually increase. When the UHV grid is built, it will cover the whole country, and the amount of ancillary services required will grow accordingly.

3.2. The imperfect pricing system of ancillary services

From the perspective of policy support, currently, the regulation of China's existing ancillary services management has no reasonable pricing standards and does not accurately reflect the actual costs and the reasonable profits of the ancillary service providers. Ancillary services are funded primarily by the quality assessment of ancillary services, and the insufficient portion is prorated by all grid-connected power plants. Because the electricity sales price is still subject to the government's pricing constraints, ancillary services do not charge for the beneficiaries (end-users), resulting in the failure to cover the costs of ancillary services providers [16].

From the perspective of the implementation effect, there exists a certain deviation in the pricing method, which lacks the consideration for the opportunity costs of generating units that provide ancillary services. Because of differences in the ability and the cost of power generation companies providing ancillary services, only limited competition is introduced into the market of ancillary services. Hence, the price cannot be determined by perfect competition, hindering the technological innovation of ancillary services. In addition, we cannot identify the relationship among opportunity costs, operating costs, price variations, consumers' special services requirements and other aspects of ancillary services.

3.3. The imperfect assessment and compensation mechanism of ancillary services

Due to the imperfect ancillary service compensation mechanism, the power grid enterprises dominate in power dispatch and transfer the related ancillary service tasks to the power generation companies. As a result, they lack the motivation to provide ancillary services so that the existing ancillary services are basically taken on by power generation companies.

From the view of the specific implementation effects, there are many practical problems in the compensation mechanism of ancillary services assessment, and the views and divergences of power generation companies are in discord. Current management approaches divide ancillary services into two categories: basic services and paid services. Basic services accept assessment, and some paid services also accept assessment when they are compensated. The compensation price is mainly based on the basic production cost. Ancillary services are funded initially by the assessment, and the insufficient portion is apportioned by participating power plants according to the electricity generation volume or electricity charges [17]. This management approach does not fundamentally change the distribution model of ancillary services, and ancillary services are still invoked in the old way. The ancillary service compensation mechanism causes the basic energy market to adopt a market economic model, while the ancillary services market is still in an unreasonable situation that is "half market-oriented and half planned". Under the existing market or trading patterns, the introduction of ancillary service management rules is bound to affect the interests of some power plants. A sharing mechanism destroys the original mode of competition, and the plants that provide few ancillary services will lose some interests obtained from basic energy market competition as a result of a certain amount of cost-sharing. Therefore, without opening the user-side and the establishment of the ancillary services market, there will always be shortfalls.

(1) The enforcement of assessment and compensation is not enough. For example, take the assessment/compensation data from the Northwest Power Grid in January 2010. The total compensation costs account for only 4/10,000 of the total electricity charges. The proportion of assessment costs of six regional power grids is also within 0.3% [18]. In addition, as an important part of ancillary service compensation, AGC,

Table 6
Assessment data of ancillary services in Northwest Grid in January 2010.

January 2010	Assessment/Ten thousand yuan	Compensation/Ten thousand yuan	Share/Ten thousand yuan
Shanxi	21.3	66.8	45.5
Gansu	73.7	35.3	−38.4
Qinghai	0.9	3.1	2.2
Ningxia	0.2	29.2	29.0
Xinjiang	36.4	16.6	−19.8
Northwest	132.5	151.1	18.6
North China	3384.0	2936.0	−448.0

thermal power peaking and in-depth voltage control enforcement are not prominent. The assessment data of ancillary services in the Northwest Grid is shown in Table 6.

(2) The standards of assessment/compensation in different provinces vary, which is not conducive to the market-oriented reforms of national ancillary services. From the assessment results in January 2010, the degrees of assessment among different provinces and autonomous regions are quite different. The greatest assessment scale of the Gansu Power Grid is 368.5 times as much as the smallest scale of the Ningxia Power Grid. The greatest compensation scale of the Shanxi Power Grid is 21.55 times as much as the smallest scale of the Qinghai Power Grid [19]. At the same time, different points of view on the rules regarding the grid scheduling and the province scheduling result in the different assessment/compensation scales of the power generation companies incorporated in the same provincial network.

(3) Wind power and captive power plants are not included in the assessment scope. To achieve large-scale wind power and solar power that is connected to the grid will require many ancillary services, but neither of the existing “two rules” includes wind power in the assessment scope. Although the regional captive power plants are included in the assessment scope, it is difficult to evaluate them when the grid-connected electricity is zero or negative as a result of settlements in the form of electricity.

(4) Hydropower provides peaking service without compensation. In light of the “two rules”, it is supposed to compensate thermal power for in-depth peaking and on/off peaking. While hydropower peaking is free of charge, ranging from 0% to 100%, the corresponding thermal power's obligatory peaking space is 40% [20]. In certain regional power systems, peaking is usually performed by hydropower. Hydropower takes on the peaking task more frequently than thermal power, but it lacks compensation.

4. Countermeasures

Ancillary services are an important means to ensure the safe and stable operation of the power system and to improve power quality. The regulation of ancillary service management published by the State Electricity Regulatory Commission is aimed at “ensuring the safe and economical operation of the power system, standardising the management of ancillary services, and promoting the sound development of the electricity industry”. Therefore, to speed up the construction of the ancillary power services market and then to construct a unified, deregulated electricity market system in line with the national conditions, formulating tariff mechanisms and policies that adapt to the market economy has an important practical significance for the guarantee of the rapid and healthy development of the national economy.

4.1. Accelerating the construction of the ancillary services market to meet the demand for ancillary services

In China's electricity market at the present stage, the perfect ancillary services market has not been established because it lacks a market mechanism, and the ancillary services are still subsidiary. In addition, the responsibilities of the main market players of ancillary services are not clear. On one hand, in the context of integrating a high share of clean energy into the grid, it is difficult to motivate the sustainable development of clean power generation technologies, which is not conducive to the stable operation of the power system and the large-scale development of clean energy. On the other hand, with the UHV construction, there is an increase in the demand for ancillary services, but the current ancillary services model cannot meet the demand of the electricity market. Hence, China should learn from the practice of the international electricity market reforms regarding ancillary services as a special type of electricity commodity and establish relatively perfect ancillary services market mechanisms to raise the enthusiasm of electricity market players for the improvement of ancillary services, meeting the increasing demand for ancillary services [21].

4.2. Developing the perfect pricing system of ancillary services

China should gradually improve the ancillary services pricing system. At the stage of “separation of power generation and transmission, limited competition”, the preliminary ancillary service charging methods should be developed. During the transition from limited competition to full competition, the ancillary service charging methods should be improved. At the stage of full competition, a competitive ancillary services market should be established, and the price of ancillary services should be determined by the market competition. Meanwhile, the corresponding ancillary services charging mechanisms should be developed, and the services are remunerated after striking a balance among initiators, beneficiaries and all the participating generation units so as to ensure the balance between income and expenses [22]. As far as pumped storage power stations, the backbone peak and the frequency regulation power plants are concerned, we should take full account of the market value of their ancillary services before they enter the competitive electricity market and give them a reasonable edge in the price formation process.

Seeing that there is no tariff space in ancillary service costs at this point, it is recommended that a forwardly competitive ancillary services market should be achieved in the electricity market following the formation of electricity purchase and sale price linkage mechanisms and the implementation of transmission and distribution prices [23]. The initial ancillary services can be recovered from power plants by a certain percentage, and then the revenues will be returned to power plants according to the reserve contribution of each plant. The charging standards can be determined according to the principle of compensating for opportunity costs. Because the grid enterprises also provide certain ancillary services, we should also consider leaving the grid with a certain proportion of the costs from transmission and distribution prices that were not formed or implemented.

4.3. Improving the assessment and compensation mechanism of ancillary services

(1) Improve research into the ancillary service compensation mechanisms. Combined with the actual conditions of regional power networks, it is necessary to explore the basic principles and implementation programs of compensation and the assessment of various types of ancillary services. Then, carry out the quantitative measurement and comparison among the various options with a reference to the actual operational data of the power system. This will identify the type and number of ancillary services provided by power generation companies, reveal the type of ancillary services that the consumers used, and offer the composition of the ancillary services costs in detail with figures such as equipment investment, fuel, operation and maintenance, personnel training, and risk compensation. [24]. Finally, the unit price of ancillary services is calculated according to the average social cost pricing principle. Currently, especially in the case of hydropower with excellent adjustment performance, it is critical to establish

the compensation mechanism for the power loss due to peaking and reactive power regulation.

(2) Because ancillary services are crucial to ensure system safety and power quality and have complex and special technical characteristics, the system needs to carry out, to a certain degree, centralised control and enforcement for ancillary services. However, at the same time, the loss of power plants, grids or users due to the provision of ancillary services should be compensated reasonably. In this way, non-commercial ancillary services, formerly provided by the supply-side, can be divided into two categories: mandatory and commercial. The pricing mechanisms are the compensation system, the bidding market or the real-time competitive pricing. At different stages of the electricity market development, the proportion of mandatory services and commercial services varies for the primary purpose of enabling the system to receive an adequate and a high-quality supply of ancillary services, taking into account the affordability and reasonable interests of buyers and sellers.

(3) Under the current electricity market circumstances where the generation side competition is dominant, the situation of scheduling ancillary services entirely by administrative means and other arrangements should be gradually changed. The way to obtain ancillary services is determined in conjunction with the characteristics of each type of ancillary service in the system. During the early construction period of the ancillary services market, in whole or in part, ancillary services are mandatory, but the providers' costs plus reasonable profits should be recovered reasonably in what is called a compensation mode. On this basis, the share of commercial services should be gradually increased, and the ancillary services for the generation side are provided through competition. Thus, a competitive market is established, which is called the competition mode. In the compensation mode, there is a need to emphasise fair dispatching, rigorous assessment, and reasonable compensation pricing. While in the competitive mode, perfect market rules, the participants' fair competition, and a reasonable price formation mechanism must be guaranteed. As the operation modes and rules of the market continue to improve, China should gradually increase the proportion of the competitive mode, resulting in the coexistence of compensation modes and competition modes. Note that no matter whether a compensation or competition mode is used, there should be a policy with a certain tendency for ancillary services on the pricing mechanism and charging principle to motivate electricity producers to provide high quality services for the grid.

5. Conclusions

China's current electricity market is still in the exploratory phase. Since the construction of the main power market, the energy market has not been perfect and still has many problems waiting to be solved. The study and practice of the ancillary services market should be consistent with the status quo and development trend of the energy market. Considering that the share of ancillary service cost in the total tariff ranks fairly low and that there is a rigid demand for ancillary services in the power system operation, the ancillary services market can take precedence over the energy market, contributing to the promotion of market-oriented reforms in China's electric power industry.

During the early construction period of the ancillary services market, China can adopt a transition mode in which the compensation and commercialisation mechanisms mix together until the completely commercialised operation mechanism is achieved. In this way, the compensation mechanism will gradually develop into a commercial operation mechanism that can fully reflect the value of ancillary services. For example, under current conditions, primary frequency regulation, reactive power control and black-start service can participate in ancillary service management in the form of long-term contracts; the AGC and the reserve service perform in competition mode, and power dispatch trading institutions organise relevant units to bid for ancillary services in the form of annual or quarterly contracts. When fully commercial operation is achieved, we can further resort to the energy market's bidding, clearing, settlement and other trading mechanisms.

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